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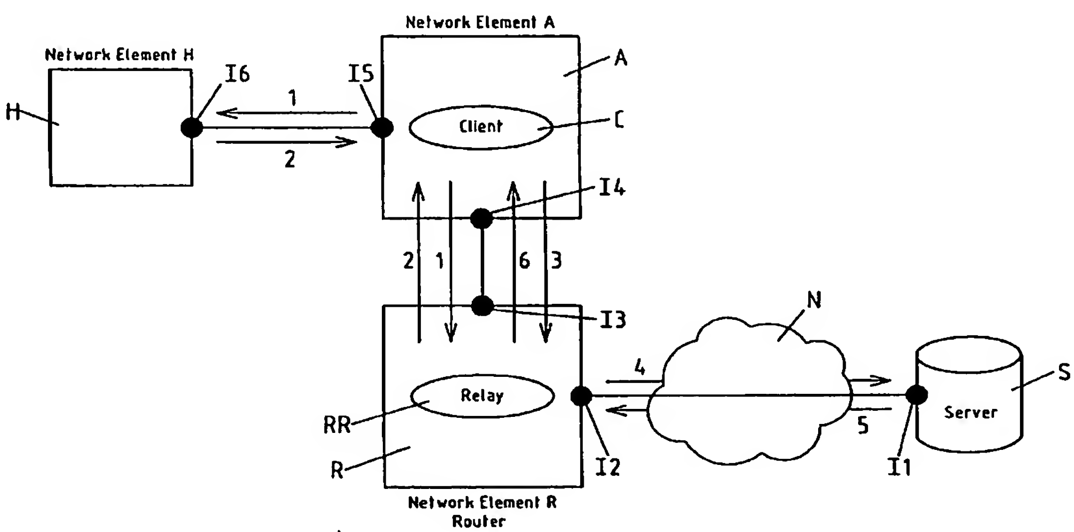
For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) **Title:** METHOD FOR AN AUTOMATIC ALLOCATION OF IP ADDRESSES



(57) **Abstract:** The invention relates to a method for an automatic assignment of IP addresses to the interfaces of network elements having at least two interfaces, by one of which they are newly connected, either directly or via other network elements, to a server of an IP based network. To minimise the necessary manual configuration when a network element with at least two interfaces is newly connected to an IP based network, under following steps are proposed: checking by said network element, which of its interfaces is connected to the server; said network element sending a configuration request via its interface linked to the server; the server of the network receiving the request, choosing and reserving as many IP addresses as needed for the new network element, and sending out a response with said IP addresses to the new network element; the new network element receiving said IP addresses and applying them on its interfaces requiring an address.

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Method for an automatic assignment of IP addresses and IP based network

The invention relates to a method for an automatic assignment of IP (internet protocol) addresses to the interfaces of network elements, especially routers, having at least two interfaces, by one of which they are newly connected, either directly or via other network elements, to a server of an IP based network. The invention equally relates to an IP (internet protocol) network comprising at least one server and network elements with more than one interface. It is understood that an IP address may be an IP host address, identifying one dedicated IP host, as well as an IP network address.

The use of networks based on the internet protocol (IP) are well known in the state of the art. Such networks are built up of different network elements, two important element types in a typical IP based network being hosts and routers. Servers may be included to serve the different network elements. A host constitutes the access for a user and has typically one interface, which connects the host to a logical IP subnetwork (LIS), i.e. the host is a member of the LIS. A member of a LIS can send IP packets directly to all other members of the same LIS. If a network element wants to communicate with other network element and the two network elements are not members of a same LIS, then there must be one or more routers between the two LISs. A router is a network element, which forwards IP packets between different LISs. Typically a router has more than one physical

interface, because the LISs typically represent also physically separated networks. The physical networks connected by the routers represent subnetworks of the whole IP network, and normally each subnetwork has its own network address.

Every host in an IP based network is assigned an IP address. The address format is comprised of a network address and a local or host address. The network address identifies the IP subnetwork to which the host is attached. The local address is a unique local address within the IP subnetwork. Using the IP addresses, two hosts on the same IP subnetwork can send packets directly to each other. Two hosts on different IP subnetworks cannot send IP packets directly to each other, instead the packets have to go via the router connecting the two subnetworks. For the routers, there can be provided an IP address for every interface, the IP address being composed again of the network address of the subnetwork, to which the interface belongs, and of a local address identifying the interface in the subnetwork. All interfaces with a dedicated IP address are numbered interfaces. For the interfaces which belong to a point-to-point link to other network elements, the assignment of a dedicated IP address is possible but not necessary, i.e. these interfaces may be numbered or unnumbered.

Typically, an IP network has a large number of hosts and the number of hosts in each subnetwork can change.. Equally, the number of other network elements can vary, for example, the number of routers when new subnetworks are to be added. In addition, the available IP address space is usually limited and should be used efficiently. In order to take such developments into account, the IP

network needs human intelligence when it comes to planning.

In the state of the art, the Dynamic Host Configuration Protocol (DHCP) is used for configuring new network elements with only one interface, especially hosts, with information from DHCP servers, which maintain a database with IP addresses. A new host searches a DHCP server and requests an IP address. In case there is a router between the host and the DHCP server, the router must have DHCP relay functionality. This method reduces the work necessary to administer an IP network. It is not known, however, how to facilitate the assignment of IP addresses and IP network addresses to new network elements with more than one interface.

It is an object of the invention to provide a method and an IP based network which minimise the necessary manual configuration when a network elements with at least two interfaces, in particular a router, is newly connected to an IP based network.

This object is reached on the one hand with the method of claim 1.

On the other hand, the object is reached by an IP (internet protocol) network comprising at least one server and network elements with more than one interface, in particular routers, which are suitable for employing the method according to one of claims 1 to 7.

The invention proceeds from the idea that, if the IP network has some known restrictions, the automatic assignment of IP addresses to network elements with more than one interface is essentially facilitated. The

invention is applicable in networks that do not require hierarchical addressing, e.g. because they are rather small. Moreover, the number of network elements has to be limited and known.

Based on those two restrictions, the method and the IP network of the invention decrease the required amount of planning in an IP based network to a minimum, because it enables the server to automatically choose and reserve IP addresses for a newly connected network element upon request by the network element. Since the distribution of the IP addresses can be carried out efficiently by the server, the address space for the addresses can be set to the minimum needed for the defined maximum number of interfaces.

Advantageous embodiments of the invention can be taken from the subclaims.

In the method according to the invention, the new network element can be connected directly to the server. Alternatively, the new network element, in particular routers, can be connected to the server via other network elements with also at least two interfaces. The other network elements comprise a relay function for the address reservation protocol, the relay function knowing the location, especially the IP address, of the server. Therefore, the other network elements are able to forward the configuration request from the new network element and the response from the server correctly. The two alternatives provide in combination a method suitable for an expansion at any location of the existing IP based network.

The new network element with more than one interface, in particular the router, may start its relay functionality after one first interface is provided with an IP address. The IP address can be dedicated to an interface in case numbered links are used. If numbered links are used, the IP address is not tied to any interface in particular.

Moreover, there might be provided a possibility to include additional information or parameters in the server's response beside the IP address, in particular by the server itself. This has the benefit that more details for the IP configuration of the new network elements or some other parameters for the new network element can be transmitted at the same time. Configurations not to be used for the whole network but being specific to a subnetwork can be achieved by including additional data by the relay of a network element the response has to pass.

In order to be able to exchange routing information, the routers of the network should run a routing protocol, in particular an Open Shortest Path First (OSPF) routing protocol.

If the new network element comprises interfaces for numbered links, in particular for Logical IP Subnetworks (LIS), the new network element requests an IP network address for each of those interfaces from the server. For the interfaces, that are already connected to existing routers, there is no need for such a request.

If the new network element only comprises interfaces for unnumbered links, the new network element preferably requests only one IP host address from the server.

In order to be useable according to the claimed methods, in a preferred embodiment of the IP network of the invention each network element with more than one interface comprises a client for checking if its interfaces are connected, directly or via another network element, to the server and for sending a configuration request to the server. Those network elements further all comprise a relay for forwarding configuration requests coming in via one of the interfaces via another one of the interfaces. The server of the network comprises means for choosing and reserving IP addresses for a network element newly included in the network in response to a received configuration request from this new network element.

In another preferred embodiment of the invention, the IP network uses the Dynamic Host Configuration Protocol (DHCP) for assigning IP addresses to the interfaces of new network elements, especially to IP hosts. The use of the DHCP may be in addition to the claimed methods. This is in particular applicable, when the interface to the existing router is numbered.

Preferably, the server of the IP network of the invention has access to a database, especially a database maintained by the server, indicating which IP addresses are allocated and which IP addresses are available.

With such a database, the server immediately knows, which addresses can be chosen and reserved for new network elements. If a network element is removed from the IP network, the IP addresses of the concerned interfaces should be identified as being available again for future allocations.

In a preferred embodiment of the IP network of the invention the at least one server of the network moreover has access to a database, in particular a DNS (domain name service) database, in which the distributed IP addresses are put into relation with a generic name of the element to which the IP address is assigned. This way, the different interfaces can be addressed easily by a generic name.

In an equally preferred embodiment of the IP network of the invention, the network is made up of point-to-point links between the network elements.

The application of the method of the invention can be seen especially with IP networks using ATM as data link layer. Accordingly, the IP network according to the invention is preferably an IP over ATM network. Still, other suitable networks can used as well.

In the following, the invention is explained in more detail with reference to drawings, of which

Fig. 1 shows an ATM network based on IP to which the method of the invention is applicable;

Fig. 2 shows a part of an IP network with newly connected components;

Fig. 3 shows a method according to the invention for one of the newly connected components of Fig. 2; and

Fig. 4 shows a preferred extension of the method of Fig. 3.

In figure 1, an IP network according to the invention can be seen. The components of the network are a server S, and, as network elements, a plurality of routers R,A and a plurality of hosts H. Each host H has one interface, each router at least two interfaces. The server S is located at a central place and connected to one of the routers R. All routers R,A that are not connected directly to the server S are connected to the server S via other routers R. Router A with interfaces I_a to I_d has been newly connected to the network.

The network elements are connected either by a point-to-point link or by a Local Area Network (LAN) L, the IP network comprising several of such subnetworks L. To each subnetwork there is assigned an IP network address, which forms part of each IP address of the interfaces belonging to the respective subnetwork. If numbered point-to-point links are used between routers and the LANs have several hosts, then the operator may not want to assign as large IP networks for the point-to-point links as for LANs. The operator may in that case define two subnetwork pools: small subnetworks for point-to-point links and larger subnetworks for LANs. The router requesting a new IP network from the server would then have to know whether it requests a LAN subnet or a point-to-point subnet for an interface. To simplify the server configuration it is therefore preferred to use unnumbered links between routers (i.e. only one pool). On the other hand, if the LANs have one or two hosts, then the subnet size in a LAN and a numbered point-to-point link could be same and one pool would be enough.

The server S is configured accordingly with a pool of subnetworks, all being able to hold the desired number of connected network elements.

Because the server has to know whether a router requests a new IP network for a LAN subnetwork or a point-to-point subnet it is simpler to use only unnumbered links between routers.

In every network element R,A,H there is included a client functionality. The client of a network element newly connected to the existing network is able to request IP addresses for its interfaces. The request is either sent to a router R or a server S connected by a point-to-point link to the requesting network element or broadcast to every node connected to the same subnetwork, depending on the connection of the new network element. Thus the request is received by all directly connected network elements. Each client of a network has an unique identifier (node ID), which enables other elements to identify each client individually. With each request, the node ID is send, such that the request can be associated with the requesting client.

In each network element with more than one interface, i.e. especially in routers, moreover a relay function is integrated. Such a functionality is needed, whenever the client of a network element cannot reach the server S directly. The task of the relay is to listen to all interfaces of its network element, and to take note if there are incoming requests from a connected network element. A received request is directly addressed and sent to one or more servers. The relay may add additional information to the request in order to enable the server S to send the response to the client.

The server S receives a request from a client of a new network element, either directly or via the relay functionality of another network element, chooses an

address, reserves it and sends it to the requesting client. The server also updates a DNS database to which it has access, so that the clients can easily be addressed by name.

If a network element has a point-to-point connection to another network element, an unnumbered link can be used. This means that the link does not have an IP network address and therefore the interfaces do not have to have IP addresses. If the connection between network elements is not a point-to-point connection, but for example a LAN with hosts, a network address is needed for the link and the interfaces of the routers have to have IP addresses.

The configuration of the new router A depends on the kind of links between the routers.

In the network of figure 1, if the links between the routers are unnumbered, the interfaces Ia, Ib and Id of the new router A can be configured to be unnumbered and interface Ic is configured as LIS interface. If it is known that the server can be found only behind an unnumbered link, the new router can try to find the server sending "server discovery" messages to the unnumbered links Ia,Ib,Id, an answer arriving via interface Ia. The router A can then requests IP host addresses or IP network addresses from the server S, depending on the other interface types. The server S can provide any free address from a pool of available addresses. Alternatively, the server S can be configured to provide dedicated addresses according to a node ID in the request message.

In the case of figure 1, the new router A will only request a network address for interface Ic. Other

addresses are not necessary, because the router A can use the IP address in interface Ic. The new router A configures the received IP addresses according to the answer from the server S and starts the relay function, which will serve other network elements below this router A. The relay function must add to the relayed requests information, which identifies the unnumbered interface from where the request came. The answer from the server S should include the same information so that the relay can forward the answer to the correct client.

If on the other hand the links between the routers are numbered, all interfaces Ia,Ib,Ic,Id of a new router A are numbered as well. First, the router uses a conventional method (DHCP) to obtain an IP address for the interface that leads towards the server. To this end, the router tries all interfaces Ia,Ib,Ic,Id and the DHCP server answers via interface Ia. Thereafter, the new router A can start reserving network addresses for the other interfaces Ib,Ic,Id. Preferably, a new router A always requests network addresses for the same size of networks for all of the interfaces Ib,Ic,Id. This way, the server does not have to keep pools of different sizes of network. When the router A has received the network addresses for the remaining interfaces, it configures the addresses to the interfaces and start its relay function. In this case, the relay function can use the same method to identify the interface of requests and answers as a DHCP relay function, because all links have IP network addresses.

The method relating to numbered links between routers employed in the network of figure 1 will be better understood with the following explanations to figures 2 to 4.

Figure 2 shows a part of a network like the one in figure 1, comprising a server S, a router R, a new router A and a host H. The server S is provided with several configured interfaces, the only one relevant in this example being referred to in Figure 2 as I1. The server S has moreover access to a DNS database, not shown in the figure, in which reserved IP addresses are assigned to the name of the client belonging to the host for which they are reserved. The router R has at least two configured interfaces I2 and I3 and a relay function. The router A also comprises at least two interfaces I4, I5. The host H is provided with only one interface I6. The router A and the host H both have a client C functionality. In the beginning, the interfaces I4, I5, I6 of router A and host H are not configured. The shown interface I1 of the server S is connected to interface I2 of the router R. The router R is connected by its interface I3 to interface I4 of the router A. Interface I5 of the router A, finally, is connected to the only interface I6 of the host H.

The router A has just been connected to the router R of the existing IP network and was switched on. Just the same, the host H has newly been connected to the router A.

Figure 3 schematically illustrates the steps of the method of the invention applied to the situation depicted in Figure 2.

Each component of Figure 2 is represented by a vertical dotted line. From left to right, the vertical lines are assigned to the host H, the network element A, the router R and the server S.

The horizontal arrows between the vertical lines represent the messages exchanged between the different components.

The proceedings according to the method of the invention applied to the IP network of Figure 2 is now explained with reference to Figure 3.

The client functionality C of the network element A checks, which of its interfaces I4,I5 are useable. Since the network is an ATM network, the presence of a cell sync on interface I4 indicates that there is another element at the end of the link. Moreover, the client functionality C checks, whether the elements reachable via interfaces I4 are configured or unconfigured by using an address resolution message (e.g. InATMARP) to evaluate the state. The signalling between network element A and host H on the one hand and network element A and router R on the other hand necessary for the checking is indicated in Figures 2 and 3 with the numbers 1 and 2 representing a first step 1 and a second step 2 carried out during the described procedure.

Interface I3 of the router R is recognised by network element A via interface I4 as being configured, interface I6 of the host H is recognised by the network element A via interface I5 as being not configured. In consequence, the client functionality C of the network element A sends a configuration request via interface I4 to interface I3 of the router R (step 3).

A relay RR running on the router R receives the request and forwards it to the server S including the IP address of the router's interface I3 (step 4).

The server S chooses an IP address that can be assigned to the interface I4 of the new network element A. One part of the address is necessarily the address of the subnetwork of the router's R interface I3 that was added by the relay RR of router R to the forwarded configuration request. The other part is one of a defined number of addresses provided for the particular subnetwork and which is not yet in use. The server S maintains for this purpose a database in which is stored for each subnetwork which addresses are allocated and which are still available. The database equally provides information on which subnetworks are allocated and which are still available.

The server S outputs a response including the chosen IP address via its interface I1 (step 5). The server may include other configuration parameters for the network element A in the response. In addition, the server S updates the DNS database so that the new network element A can be addressed by name.

The relay RR of the router R receives and forwards the response of the server S to the network element A via the interfaces I2 and I3 (step 6). Also at this point, additional configuration data relevant for the particular subnetwork may be included in the response to the new network element A.

The new network element A receives the response and applies the IP address included in the response on the used interface I4. In case other parameters had been included in the server's S response, they are also utilised for configuration.

The new network element A can now start its relay functionality RA, as depicted in Figure 4.

The network element A checks, if one of its interfaces I5 currently not supplied with an IP address could be in usage. It recognises or knows that interface I5 (steps 7 and 8) is numbered, but the subnet address is not yet allocated. A configuration request for interface I5 is therefore sent via the local relay RA of the network element A (step 9) and the connected network N, which may consist of a plurality of routers R (step 10) to the server S, the routers R not being shown in this figure. The configuration request indicates that a new subnetwork has to be used. The server S first chooses and reserves an address for a new subnetwork that is still available according to a consultation of the proper database. Thereafter, the server S chooses and reserves an IP address for interface I5, composed of the address of the new subnetwork and of a part identifying the interface I6 within the new subnetwork and sends it back via the network N and the relay RA of network element A to the interface I5 (step 11). The IP address chosen by the server S is applied to interface I5, this interface I5 being configured as well thereupon.

In the following, interface I6 of the host H still has to be configured. The host H recognises by a check with an InATMARP message that interface I5 of the network element A is configured and sends a configuration request to the server S via the relay RA of the network element A. This time, the relay RA of the network element A includes the address of the subnetwork of its interface I5 in the request. The further proceeding is the same as described for the configuration of the first interface I4 of the network element A.

In order to enable the operator to watch over the address usage in the network, there is provided a documentation tool.

CLAIMS

1. Method for an automatic assignment of IP (internet protocol) addresses to the interfaces of network elements (A), especially routers, having at least two interfaces (I4,I6), by one of which they are newly connected, either directly or via other network elements (R), to a server (S) of an IP based network, characterised in that the method comprises the steps of:

a) checking by said new network element (A), which of its interfaces (I4,I5) is connected to the server;
b) said new network element (A) sending a configuration request via its interface (I4) linked to the server;
c) the server (S) of the network receiving the request, choosing and reserving as many IP addresses as needed for the new network element (A), and sending out a response with said IP addresses to the new network element (A);
d) the new network element (A) receiving said IP addresses and applying them on its interfaces requiring an address.

2. Method according to claim 1, characterised in that the new network element (A) is connected to the server (S) via other network elements (R), said other network elements (R) comprising at least two interfaces and a relay function for the address reservation protocol, the relay function knowing the location in particular the IP address of the server (S).

3. Method according to claim 1, characterised in that the new network element (A) starts its relay

functionality after at least one IP address or IP network address has been assigned.

4. Method according to claim 1, characterised in that additional information or parameters are included in the server's (S) response to a configuration request from a new network element (A) beside the IP address, either by the server (S) or by the relay (R) of a network element (R) the response has to pass.

5. Method according to claim 1, characterised in that all network elements of the network that are routers run a routing protocol to exchange routing information in particular an Open Shortest Path First(OSPF) routing protocol.

6. Method according to claim 1, characterised in that if the new network element comprises interfaces for numbered links, in particular for Logical IP Subnetworks (LIS)the new network element requests an IP network address for each of those interfaces from the server (S).

7. Method according to claim 1, characterised in that if the new network element only comprises interfaces for unnumbered links, the new network element requests only one IP host address from the server (S).

8. IP (internet protocol) network comprising at least one server (S) and network elements (A) with more than one interface, characterised in that said network elements (A) are suitable for employing the method according to one of claims 1 to 7.

9. IP (internet protocol) network according to claim 8, characterised in that
each network element (A) with more than one interface (I2,I3) comprises a client (C) for checking if its interfaces (I4,I5) are connected directly or via another network element (R) to the server (S) and for sending a configuration request to the server (S), in that each network element (R) with more than one interface (I2,I3) comprises a relay (RR) for forwarding configuration requests coming in via one of the interfaces (I3) via another one of the interfaces (I2), and in that the server (S) comprises means for choosing and reserving IP addresses for a network element (A) newly included in the network in response to a received configuration request from this new network element (A).

10. IP network according to claim 8, characterised in that it is suitable for using the Dynamic Host Configuration Protocol (DHCP) for assigning IP addresses to the interfaces of the new network elements (H), in particular to IP hosts.

11. IP network according to claim 8, characterised in that the network is made up of point-to-point links between the network elements (S,H,R).

12. IP network according to claim 8, characterised in that the server (S) has access to a database, in particular a database maintained by the server indicating which IP addresses are allocated and which IP addresses are available.

13. IP network according to claim 8, characterised in that the server (S) has access to a database, in particular a domain name service (DNS) datbase, in which

all reserved IP addresses are related to the name of the network element (A) to which the IP address is assigned.

14. IP network according to claim 8, characterised in that ATM is used as data link layer.

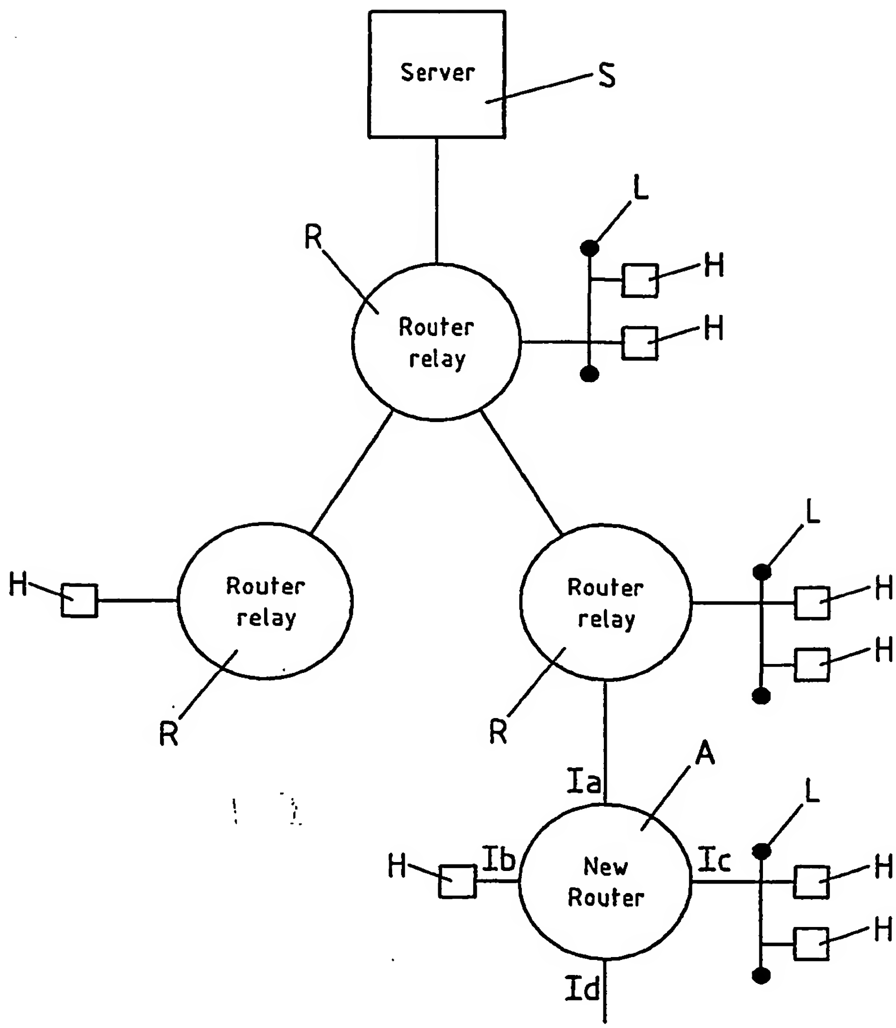
Server
S
L
R
H
Router
relay
H
Router
relay
L
H
Router
relay
H
H
R
R
Ia
A
L
H
Ib
New
Router
Ic
H
H
Id

Fig.1

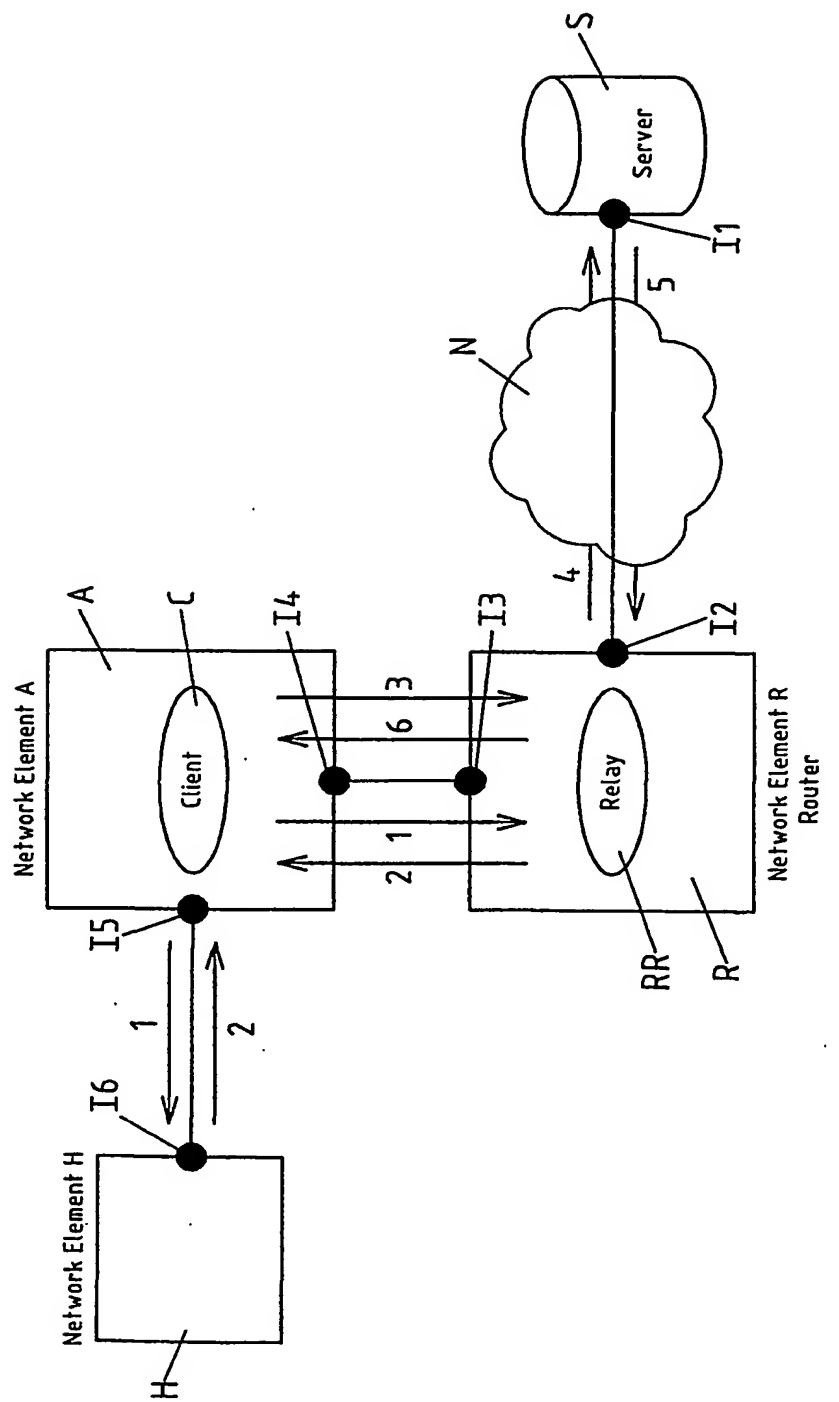
S
Server
I1
5
N
4
I2
A
Network Element A
C
Client
I4
I3
3
6
1
2
Relay
Network Element R
Router
RR
R
I5
1
2
I6
Network Element H
H

Fig.2

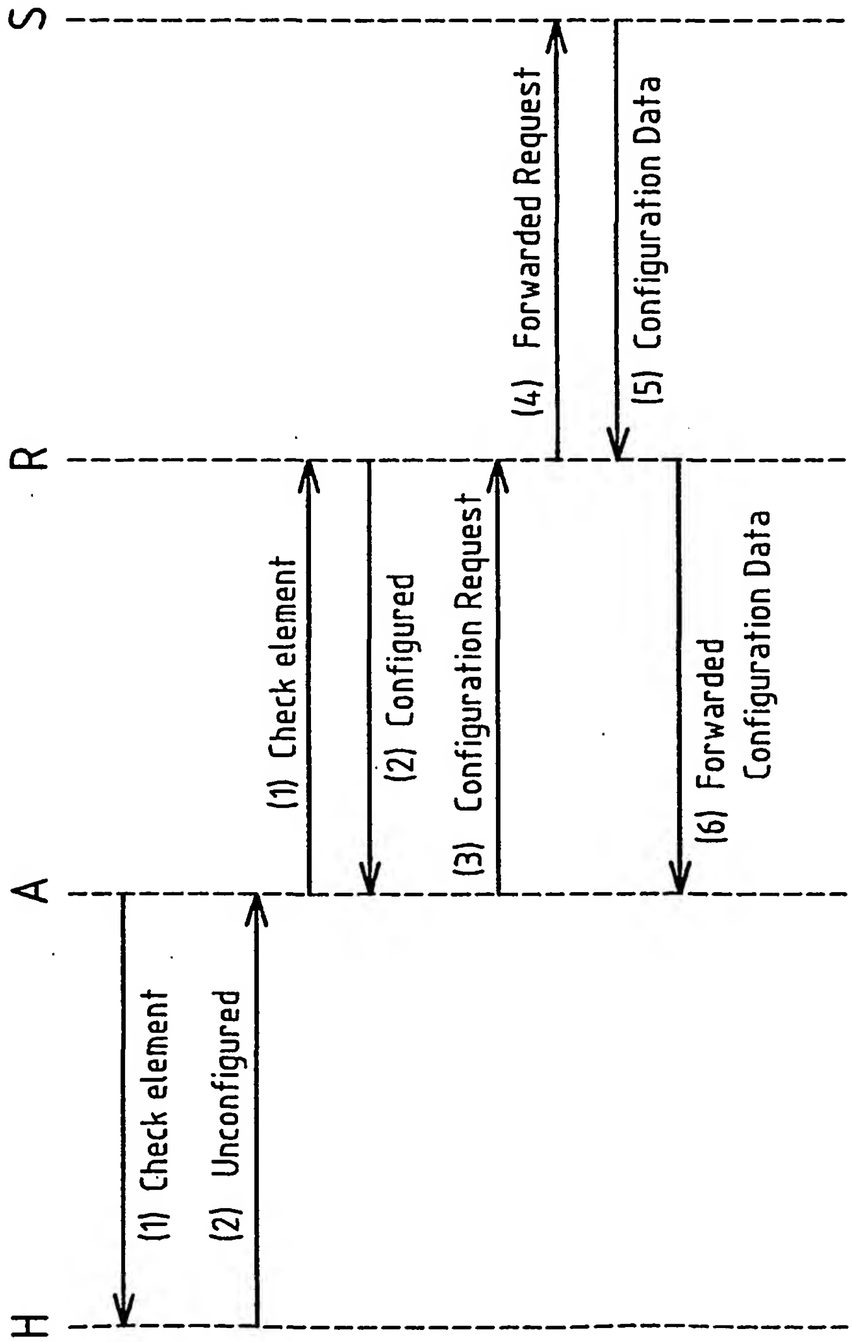
S
R
A
H
(1) Check element
(2) Unconfigured
(1) Check element
(2) Configured
(3) Configuration Request
(4) Forwarded Request
(5) Configuration Data
(6) Forwarded Configuration Data

Fig.3

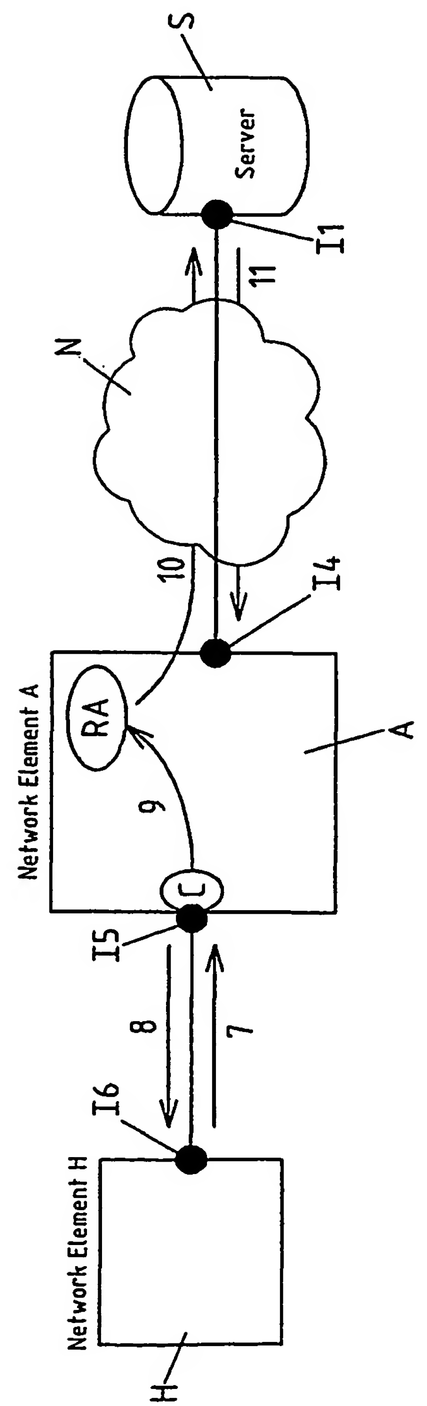
S
Server
I1
11
N
10
I4
Network Element A
RA
A
9
C
I5
8
7
I6
Network Element H
H

Fig.4

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 00/04147

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04L29/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	R. DROMS: "RFC 1541, Request For Comments, Dynamic Host Configuration Protocol." RETRIEVED FROM THE INTERNET, AT WWW.IETF.ORG, XP002164347	1-4,6-12
Y	paragraph '0002! paragraph '0003! paragraph '03.1! figure 3	5,13,14

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[X] Further documents are listed in the continuation of box C.

[ ] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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Date of the actual completion of the international search	Date of mailing of the international search report
30 March 2001	12/04/2001

Name and mailing address of the ISA	Authorized officer
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PERKINS C E ET AL: "USING DHCP WITH COMPUTERS THAT MOVE" WIRELESS NETWORKS, ACM, US, vol. 1, no. 3, 1 October 1995 (1995-10-01), pages 341-353, XP000538245 ISSN: 1022-0038 paragraph '0002! ---	1-4,6-12
X	D.E.COMER: "Internetworking with TCP/IP, Vol I: Principles, Protocols and Architecture, 3rd edition." 1995 , PRENTICE-HALL , US XP002164348 paragraph '21.9! paragraph '21.10! paragraph '21.11! paragraph '21.12! ---	1-4,6-12
Y	PERLMAN R: "A COMPARISON BETWEEN TWO ROUTING PROTOCOLS: OSPF AND IS-IS" IEEE NETWORK, IEEE INC. NEW YORK, US, vol. 5, no. 5, 1 September 1991 (1991-09-01), pages 18-24, XP000248469 ISSN: 0890-8044 the whole document ---	5
Y	CHUL-JIN PARK ET AL: "The improvement for integrity between DHCP and DNS" PROCEEDINGS. HIGH PERFORMANCE COMPUTING ON THE INFORMATION SUPERHIGHWAY, XX, XX, 28 April 1997 (1997-04-28), pages 511-516, XP002110636 the whole document ---	13
Y	GUARENE E ET AL: "IP AND ATM INTEGRATION PERSPECTIVES" IEEE COMMUNICATIONS MAGAZINE, IEEE SERVICE CENTER. PISCATAWAY, N.J, US, vol. 36, no. 1, 1988, pages 74-80, XP000739155 ISSN: 0163-6804 the whole document -----	14